998-191

4.5 PSP Cover Sheet (Attach to the front of each proposal)

Proposal Title: Geomorphic Model for Demonstration and Feasibility Assessment of Set-Back Levees: Bay-Delta River Systems

Applicant Name: Eric Larsen and Jeff Mount
Mailing Address: University of California, Davis Davis, CA 95616 Kerr Rm. 183
Telephone: (530) 752-8336
Fax: (530) 752-0951
Email: ewlarsen@ucdavis.edu

Amount of funding requested: $ 104,458 for 2 years

Indicate the Topic for which you are applying (check only one box).

- ☐ Fish Passage/Fish Screens
- ☒ Habitat Restoration
- ☐ Local Watershed Stewardship
- ☐ Water Quality
- ☐ Introduced Species
- ☐ Fish Management/Hatchery
- ☐ Environmental Education

Does the proposal address a specified Focused Action? X yes ____ no

What county or counties is the project located in? not specific

Indicate the geographic area of your proposal (check only one box):

- ☐ Sacramento River Mainstem
- ☐ Sacramento Trib: ____
- ☐ San Joaquin River Mainstem
- ☐ San Joaquin Trib: ____
- ☐ Delta: ____
- ☐ East Side Trib: ____
- ☐ Suisun Marsh and Bay
- ☐ North Bay/South Bay: ____
- ☒ Landscape (entire Bay-Delta watershed)
- ☐ Other: ____

Indicate the primary species which the proposal addresses (check all that apply):

- ☐ San Joaquin and East-side Delta tributaries fall-run chinook salmon
- ☐ Winter-run chinook salmon
- ☐ Late-fall run chinook salmon
- ☐ Delta smelt
- ☒ Splittail
- ☐ Green sturgeon
- ☒ Migratory birds
- ☐ Other: ____
- ☐ Spring-run chinook salmon
- ☐ Fall-run chinook salmon
- ☐ Longfin smelt
- ☒ Steelhead trout
- ☐ Striped bass
- ☐ All chinook species
- ☒ All anadromous salmonids

Specify the ERP strategic objective and target (s) that the project addresses. Include page numbers from January 1999 version of ERP Volume I and II:

Stream Meander, St.Objective (p.43 Vol I); NaturalFloodplains and Floodplain Process Target 1 (p375); Restore aquatic, wetland, riparian habitats, St. Objective (Vol.I p. 103-104); Reestablish frequent innundation by setting back levees,St. Objective (Vol. I, p. 439)

Indicate the type of applicant (check only one box):

- ☐ State agency
- ☐ Public/Non-profit joint venture
- ☐ Local government/district
- XX University
- ☐ Federal agency
- ☐ Non-profit
- ☐ Private party
- ☐ Other: ______________________

Indicate the type of project (check only one box):

- ☐ Planning
- ☐ Monitoring
- XX Research
- ☐ Implementation
- ☐ Education

By signing below, the applicant declares the following:

1.) The truthfulness of all representations in their proposal;

2.) The individual signing the form is entitled to submit the application on behalf of the applicant (if the applicant is an entity or organization); and

3.) The person submitting the application has read and understood the conflict of interest and confidentiality discussion in the PSP (Section 2.4) and waives any and all rights to privacy and confidentiality of the proposal on behalf of the applicant, to the extent as provided in the Section.

Eric Larsen
Printed name of applicant

Eric Larsen
Signature of applicant

Geomorphic Model for Demonstration and Feasibility Assessment of Setback Levees: Bay-Delta River Systems

Primary contact: Eric W. Larsen
Department of Geology, University of California, Davis, CA 95616
ph: (530)752-8336; fax (530)752-0951; e-mail: ewlarsen@ucdavis.edu

Jeffrey F. Mount
Center for Integrated Watershed Science and Management,
University of California, Davis, CA 95616
ph: (530) 752-7092, fax: (530) 752-0951, e-mail: mount@geology.ucdavis.edu

Type of organization and tax status: Institution of higher education/exempt

Tax identification number: 94-6036494-W

In coordination and cooperation with:

The Nature Conservancy
California Department of Water Resources
U.S. Army Corps of Engineers Comprehensive Study Group
US Fish and Wildlife Service

Executive Summary

Project description and primary biological/ecological objectives: Setback levees have been supported as an approach to multi-objective floodplain management on the Sacramento and San Joaquin Rivers, and are commonly recommended as a way to restore geomorphic and ecosystem function in riverine habitats. However, the benefits of setback levees, as weighed against the costs, have yet to be conclusively demonstrated to agency personnel and the public. This project seeks funding to develop a geomorphic model that allows simulation and demonstration of the response of riverine systems to levee removal and setback. The prototype model can be used in leveed reaches of rivers in the Bay-Delta system. This model also provides data for a riparian habitat model that is currently being developed by collaborator, Steven E. Greco, of UC Davis.

The levee setback simulations will be based upon a model that is currently in development. The model is a physics-based meander migration model that predicts channel evolution in response to measured or estimated hydraulic and geologic conditions. This model can ultimately be linked with an empirical model of the response of riparian forest and floodplain vegetation to channel dynamics and floodplain inundation. The geomorphic model will be used to simulate channel and floodplain changes in response to levee setbacks.

When applied to various levee setback designs, the model can be used to demonstrate and estimate spatial and temporal changes in floodplain development. These simulations can be used to inform decisions on appropriate magnitude of setbacks, ecosystem benefits, and potential third party benefits and impacts such as compatible land uses, placement of infrastructure, water quality impacts, and economic impacts. Additionally, the visualizations developed for CALFED and collaborating partners in this project will demonstrate the evolution of river meanders and their associated floodplains in response to levee setbacks and renewed channel migration. This will add to the public understanding of promoting natural processes as a means of restoration.

Approach/tasks/schedule: This project involves four tasks to be completed within two years of the start date. UC Davis researchers and staff, in collaboration with project partners, will complete all tasks. The California Department of Water Resources and the U.S. Army Corps of Engineers have agreed to supply sample hydrologic, geologic, land use, and topographic information, in order to develop prototype levee setback scenarios.

Task 1: Develop levee and infrastructure-placements component of migration model (Year 1)
Task 2: Apply model to simulate levee setback scenarios (First half, Year 2)
Task 3: Develop interactive computer visualization of model output (Second half, Year 2)
Task 4: Prepare model simulations, provide report and recommendations (Second half, Year 2)

Justification for project and funding by CALFED: As noted in the CALFED ERPP, the conservation and improvement of ecosystems within the Sacramento River Basin involves restoring channel dynamics and the links between the channel and its floodplain. This project will provide a tool to allow CALFED and other decisionmakers the method to evaluate the magnitude and timing of habitat that is likely to be created if levees are set back and geomorphic processes are restored. In addition, this tool can be used for public demonstration of the value and implications of setback levees and the restoration of geomorphic function, and aid in designing setbacks that minimize third party impacts. The General Bay-Delta Focused Action "*Develop ecologically-based hydrologic models*" is directly addressed by this project.

Budget costs and third-party impacts: This project seeks $104,458 for a two-year project. Most of the cost is salaries and overhead for a research scientist and post-graduate researcher.
Task 1: Develop levee component of model (Year 1) $52,662
Task 2: Apply migration model to simulate levee setback scenarios (First half, Year 2) $20,848
Task 3: Develop visualization code (Second half, Year 2) $13,924
Task 4: Prepare model simulations, report and recommendations (Second half, Year 2) $17,024
Total $104,458
No negative third party impacts are anticipated with this proposed project. The model and demonstration tool can ultimately be utilized by a broad range of stakeholders and agencies, including CALFED, in the understanding and analysis of levee setbacks.

Applicant qualifications: Eric W. Larsen, Ph.D. (1995), Assistant Research Scientist, Department of Geology, University of California, Davis. Area of emphasis: fluvial geomorphology, riverine restoration, river mechanics and sediment transport.
Jeffrey F. Mount, Ph.D. (1980), Professor and Chair, Department of Geology, University of California, Davis. Director, UD Davis Center for Integrated Watershed Science and Management. Area of emphasis: sedimentology, fluvial processes, flood management.

Monitoring and data evaluation: Because the levee setback scenarios are not site-specific, this project does not entail monitoring. Fundamental questions will be evaluated as follows: 1)What is the dynamic interaction between levees, hydrology and meander migration? Method: Measure the magnitude of lands eroded and deposited. Tabulate a time-rate of areal erosion and deposition. Vary the hydraulic input parameters, like discharge, to examine the effect of changing hydrology. 2) What will be the geomorphic response to levee setbacks? Method: Measure the magnitude of lands eroded and deposited. Tabulate a time-rate of areal erosion and deposition. Plot this against the distance of levee setback. 3) Can setback distances be optimized to promote multi-purpose ecosystem and flood management objectives? Method: Plot the magnitude and time-rate of lands eroded and deposited against the distance of levee setback. Determine optimum distance for various defined objectives. 4) How will different setback schemes effect sediment transport? Method: Tabulate the change in longitudinal bed slope for various setback schemes. Use the slope to estimate changes in sediment transport rates associated with different schemes.

Local support/coordination with other programs/compatibility with CALFED objectives: This project will rely upon close coordination between UC Davis, The Nature Conservancy, ACOE Comprehensive Study Group, DWR and USFWS. We will request that members of each agency participate in an advisory team to direct the development of the model and guide simulations, providing for consistency and coordination with other floodplain management programs. Additionally, the project will interact directly with the on-going California Interagency Floodplain Management Coordination Group and the ACOE Sacramento and San Joaquin Comprehensive Study. The Comprehensive study specifically recommends meander migration simulations. We will coordinate with the U.S. Army Corps of Engineers to develop a computer model that is compatible with the recommendations outlined in the comprehensive plan. In addition, the meander migration model will provide a valuable component of the Comprehensive Study's Floodplain Ecosystem Function Model. This project will provide a "rational, science-based model to aid in decision making in ecosystem-based management" (CALFED ERPP p. 3, Vol. 1.)

Project Description

Project description and approach

Levees have played a vital role in flood management and water supply within the Central Valley and the Bay-Delta region for the past 150 years. In reviews of flood management following the Mississippi River floods of 1993 and the 1997 New Year's floods of the Central Valley, multiple public and private entities have noted that close levees--those levees which confine river flows to a narrow floodway adjacent to river channels--are often in conflict with multi-objective floodplain management goals. Setback levees, which expand the area of the floodway, increase flood conveyance and storage, and reduce maintenance costs, have been discussed as an alternative to close levees in some regions of the Central Valley. Additionally, setback levees have been identified within the ERPP and at CALFED meetings and hearings as a potential method for restoring ecosystem function within riparian habitats in the lower Sacramento and San Joaquin rivers.

While there is broad, but not unanimous advocacy for setback levees within the Sacramento and San Joaquin Basin, the benefits of such an approach have been largely assumed, but not proven. Although currently a topic of consideration by the California Interagency Floodplain Management Coordination Group, no rigorous evaluations have been completed demonstrating that the considerable costs associated with setback levees are matched by the reductions in flood damages and the quantity of habitat generated.

The geomorphic response of a river to levee setbacks remains a key unknown and limits our ability to design setback levees and to accurately assess their benefits for ecosystem restoration and flood management. When close levees are removed or set back, rivers will respond through development of a new, dynamic channel planform that reflects newly-imposed hydrologic and geologic conditions (Brookes, 1989; Mount, 1995, 1997). Predicting the evolution of this planform through time is key to the determination of the design and placement of the setbacks and their performance in large floods. Channel migration will control the spatial and temporal evolution of linked aquatic, riparian, floodplain and wetland habitats. The amount of new habitat created will play a key role in assessing the benefit of levee setback designs. In addition, it will determine what types of land use practices are likely to be compatible with setbacks. To date, being able to answer this fundamental question--*how will the river change* ---limits our ability to accurately assess the geomorphic impacts of levee setbacks.

The goal of this project is to develop a demonstration and modeling tool that will support evaluation of the response of single-channel meandering rivers to various levee setback configurations. When completed, this tool can be used by decisionmakers and designers to estimate short- and long-term change in channel planform and associated riparian, floodplain and wetland habitat areas. In addition, the computer visualizations associated with this model can be used as a demonstration tool for private and public stakeholders to illustrate geomorphic processes in response to levee setbacks.

This two-year project will involve a physics-based meander migration model developed by Dr. Eric Larsen. The model will be GIS-based and interactive, with on-screen adjustments in the parameters that control the patterns and rates of channel change. The output from the geomorphic model will be displayed using visualization software ideal for demonstration purposes.

In order to evaluate the utility of the geomorphic model and to develop visualizations for demonstration purposes, we will conduct initial modeling runs on synthetic close-leveed and setback reaches that would provide a prototype for applications to river channels in the Bay-Delta system. This tool in no way presumes to judge where levee set back should be performed. This project will provide an effective tool to evaluate and illustrate levee set back possibilities. We will model the potential channel response of the river to changes in hydrology and physical conditions associated with levee setbacks. The model will also be used to illustrate the impacts of changing land use types and infrastructure, such as irrigation diversions, bridges and revetment, on channel planform evolution. This proposal is envisioned as the first phase requirement for a more comprehensive study to assess the potential benefits and impacts to third parties that would be required for implementing setback levees.

Proposed scope of work

Task 1: Develop levee and infrastructure-placements component of migration model (Year 1)

With DWR and USFWS funding, Dr. Eric Larsen has developed a numerical model of meander migration for several reaches of the Sacramento River between Colusa and Red Bluff. Previous to that, the same model was shown to effectively predict meander migration of reaches of the Mississippi River (Larsen, 1995). The model, which combines a model for the velocity flow field (Johannesson and Parker, 1989) and bank erosion (Ikeda et al., 1981), has been successful in predicting channel migration (Larsen et al., 1997; Larsen, Mount, and Schladow, in review.) The model requires input values for the channel planform and five variables that represent the hydrology and hydraulic characteristics of the channel: characteristic discharge, width, depth, slope and median particle size. The model can use empirical optimization methods to calibrate the hydraulic roughness and the bank erosion rate, or these parameters can be estimated. The model currently runs on a Pentium-based PC in MATLAB. In order to effectively use this meander migration model for evaluating levee set backs, several new developments must take place. Computer code needs to be developed that allows the incorporation of riprap, levees and other hard points, such as irrigation diversions and bridges, within the model runs. This prototype code requires installation and testing within the model. The model will be applied to synthetic reaches of river channel. At this point in development of the levee setback simulations, no attempt will be made to apply it to a particular demonstration area. We expect that the prototype will be useful throughout a range of river reach locations in the Bay-Delta system.

The MATLAB-based meander migration model will be presented to CALFED personnel and reviewed by the advisory group at the end of the first year.

Task 2: Apply migration model to simulate levee setback scenarios (First half of Year 2)

Following completion of the prototype geomorphic model, we will develop a suite of model runs that illustrate the potential impacts of various levee setback scenarios. Selection of these scenarios will be done in close coordination with DWR, ACOE, USFWS, and TNC to select scenarios that best illustrate the impacts of levee setbacks.

Task 3: Develop computer model for visualization of model output (Second half of Year 2)

In order to develop an interactive visualization tool that models and demonstrates the response of a river to levee setbacks, we will develop the meander migration model with output displayed using a visualization package. Currently we plan to display the output using MATLAB, which is widely used for analysis and presentation of spatially-based data and for programming. We will also explore the possible linkage of the model to ARCVIEW. UC Davis currently maintains site licenses, and considerable expertise, for this program. In addition, MATLAB has a mapping toolbox, which may be effective in developing the visualization package.

Task 4: Prepare model simulations, report and recommendations (Second half of Year 2)

The suite of model runs will be assembled into a collection of digital animations that can be used for public presentations that demonstrate and discuss the impacts of levee setbacks. These animations will be in a format that can be used with a Pentium-based laptop PC.

In order to test the model's ability to enhance public understanding of natural processes and functions as a means of restoration, we will hold two meetings. Interested participants from both the public and private sector will be invited to view the model and discuss questions and issues relative to the demonstration tool and its application. A summary of these meetings will be included in the final report.

At the end of this project, and in consultation with project collaborators, we will present to CALFED a final report that includes an assessment of the prototype geomorphic model, including selected model simulation runs. The report will focus on issues that should be addressed, using the model, in design and evaluation of levee setbacks.

If only a portion of the proposal is to be funded, the following combinations are possible: 1, 1+2, 1+2+3, or 1+2+3+4.

Location and/or geographic boundaries of project

This project is not intended to address a specific geographic area, but rather to have broad application as a demonstration and modeling tool for levee setback considerations throughout the CALFED region of interest. The simulations of the model will be based on hypothetical close-leveed reaches that are similar in character to river reaches in the Bay-Delta region. We will use hydraulic, vegetative, and geologic input data that are typical of rivers in this region. Our intent is to develop an expert tool to evaluate and demonstrate geomorphic response to various levee set back strategies. The project in no way is designed to judge where levee set back should be made, but it is designed to be a tool to evaluate and demonstrate geomorphic response to levee set back.

Ecological/Biological Benefits

As noted above, the assessment of the benefits and costs of levee setback design hinge upon being able to determine the channel response to levee changes. When applied, the geomorphic model proposed here will provide an important tool for addressing and demonstrating a series of local and watershed-scale issues. Some of the questions that can be addressed by use of the model include:

- setback design to optimize habitat formation, flood reduction, reduction of levee maintenance and reduction of costs and impacts to local land use activities
- quantitative determination of spatial extent of potential short- and long-term changes in aquatic, riparian, wetland and floodplain habitat
- magnitude of planform change and impact of infrastructure
- based on this work, local and regional changes in flood stage associated with levee setback options, including changes in stage associated with changes in habitat and land use
- cumulative water quality changes associated with increased wetland, riparian and floodplain habitat
- economic analysis of setbacks on farm-based economies, including identification of farming practices that are compatible with setback levees
- economic analysis of the value of changes in habitat, water quality, levee maintenance and construction

It is anticipated that this model will directly assist the California Interagency Floodplain Management Coordination Group's on-going effort to develop an economic model for alternative and non-structural floodplain management.

As the CALFED ERPP Proposal Solicitation Package points out, there is limited public understanding of the benefits associated with restoration of geomorphic function in riverine settings and the links between rivers and their floodplains. One of the benefits of this project will stem from the computer simulations that will allow CALFED and agency personnel the opportunity to demonstrate the long-term changes and benefits associated with channel restoration. The simulations developed for the prototype model will be in easy-to-use format and will run on a Pentium-based laptop PC. Additionally, the variables that control channel planform change will be adjustable using on-screen buttons in MATLAB, allowing presenters to illustrate the influence of hydrologic and land use changes on rivers.

Some **fundamental questions** to be evaluated through this project are: What is the dynamic interaction between levees, hydrology and meander migration? What will be the geomorphic response to levee setbacks? Can setback distances be optimized to promote multi-purpose ecosystem and flood management objectives? How will different setback schemes effect sediment transport? The model can be used to develop a permanent body of knowledge related to the geomorphic response to setback levees. It is therefore "self-sustaining" and directly contributes to the ecosystem-based approach.

Background and ecological/biological objectives: As the CALFED ERPP notes, the health of riparian ecosystems and associated aquatic communities is tied directly to the maintenance of geomorphic processes. Riparian plant communities that remain within the alluvial floodplains of the Bay-Delta region are dynamic, with adaptations to cycles of flooding, erosion and deposition. The fish and wildlife species that depend upon these communities are adapted to take advantage of disturbances and cycles within these habitats. Studies in this region indicate that fish biomass is positively correlated with flooding onto the floodplain (Roux and Copp, 1996; Bayley and Peter, 1989; Ward and Stanford, 1989), and avian diversity is tied to riparian forest diversity and cover (Hehnke and Stone, 1978).

Land use practices have dramatically reduced the historical extent of riparian, wetland and floodplain habitat of the Bay-Delta region over the past century (Roberts, Howe, and Major, 1977; Katibah et al., 1984; Scott and Marquiss, 1984). The decline has taken place in several forms: loss of riparian forests through land conversion, separation of the links between the aquatic and terrestrial zones, and water management or land use practices that reduce or eliminate disturbance and geomorphic function.

The loss of riparian habitat and geomorphic function within the Bay-Delta watershed has been driven, in part, by the methods used to reduce flood damages within the basin. The extensive close levees that line many of the river systems in this region have contributed to the decline in habitat, and the associated decline in species richness. This project develops a tool that can be used to reduce the following stressors: Hydrologic Isolation of Floodplain or Marshplain; Physical Isolation of Floodplain or Marshplain; Elimination of Fine Sediment Replenishment; Alteration of Channel Form; Prevention of Channel Meander; Isolation or Elimination of Sidechannel Tributaries; Reduction of Gravel Recruitment; Channel Aggradation Due to Fine Sediments; Loss of Existing Riparian Zone or Lack of Regeneration Potential; Increased Water Temperature.

Species: A tool for assessing levee set back will provide significant benefits for the following priority species: Winter-run, spring-run, late-fall-run and fall-run chinook salmon; splittail; steelhead trout; green sturgeon. Other CALFED priority species and wildlife directly benefiting from this project include resident fish, American shad, Swainson's hawk, western yellow-billed cuckoo, bank swallow, shorebird and wading bird guilds, neo-tropical migratory birds, upland game, valley elderberry longhorn beetle, and bald eagle.

Linkages: **SB1086.** The existing meander migration model has been used in the SB1086 program, a collaborative effort of local landowners, agencies and other interested parties, which has been working since 1987 to establish a plan to preserve and manage a continuous riparian ecosystem along a 222-mile segment of the Sacramento River. This proposal builds on work that was initiated in close coordination with the SB1086 program.

Implementation of Riparian Corridor Management along the Woodson Bridge Subreach of the Sacramento River (1999 CALFED Proposal). The SB1086 program is moving into an implementation phase that includes forming a locally-based nonprofit riparian habitat management organization. Addressing ongoing erosion at the Woodson Bridge State Recreation Area through the restoration of natural channel process will be one of the first tasks of the organization. The Department of Water Resources in Redbluff is seeking CALFED funding to implement the riparian corridor management plan. The existing migration model is planned to be used in modeling the meander migration of the Woodson Bridge area and alternative bank stabilization plans. This proposes levee setback component will coordinate closely with that effort.

U.S. Army Corps of Engineers Comprehensive Study. The Comprehensive study specifically recommends meander migration simulations similar to those proposed here. We will coordinate with the USACOE in developing the levee setback modeling tool in accord with suggestions outlined in the comprehensive plan. In addition, the meander migration model will be a valuable component of the Comprehensive Study's Floodplain Ecosystem Function Model.

A tool for assessing the geomorphic impact of setting back levees will promote natural floodplain development and addresses the following Ecosystem Restoration Program strategic objectives:

Category	Strategic Objective	ERP reference
Ecological Process: Stream Meander Natural Floodplains and Flood Processes	Increase the extent of freely meandering reaches; Re-establish inundation of floodplains by setting back levees.	Vol. 1, p. 43
Habitat:	Restore aquatic, wetland, riparian habitats	Vol. 1, p. 103-104
Species: Sacramento Winter-run, spring-run, fall-run,and late-fall run chinook salmon	Restore winter-run, spring run, fall-run, and late-fall run chinook salmon to the Sacramento River and Bay-Delta Estuary	Vol. 1, p. 220-223
steelhead trout	Restore steelhead to Central Valley streams and the Bay-Delta estuary	Vol. 1, p. 229
Swainson's hawk	Restore Swainson's hawk populations	Vol. 1, p. 249
Species: Valley Elderberry Longhorn Beetle	Maintain valley elderberry beetle habitat	Vol. 1, p. 286-287
Species: western yellow-billed cuckoo	Restore populations of yellow-billed cuckoo throughout its historical range	Vol. 1, p. 304
Species: bank swallow	Increase the number of breeding colonies of bank swallow in the Central Valley	Vol. 1, p. 307
Species: least Bell's vireo	Restore least Bell's vireo to representative habitats throughout its former range	Vol. 1, p. 312
Species: California yellow warbler	Restore and protect habitats used by neotropical migrant birds	Vol. 1, p. 314
Species: little willow flycatcher	Restore little willow flycatcher populations	Vol. 1, p. 317-318
Species: native resident fish species	Reverse the decline of native resident fishes	Vol. 1, p. 347
Species: shorebird and wading bird guild	Provide high quality habitat that allow shorebirds [access to both feeding and nesting	Vol. 1, p. 355-356
Species: waterfowl	Enhance populations of waterfowl for harvest	Vol. 1, p. 360
Species: neotropical migratory bird guild	Restore and protect habitats used by neotropical migrant birds	Vol. 1, p. 363
Stressor: invasive riparian plants	Eliminate, or control all undesirable non-native species, where feasible.	Vol. 1, p. 478
Stressor: levees, bridges and bank protection	Reestablish frequent inundation by setting back levees	Vol. 1, p. 439

System-Wide Ecosystem Benefits: Restoration of river processes, and modeling efforts associated with this process support the goals of the following programs: Sacramento River Riparian Habitat Program: Central Valley Project Improvement Act; Sacramento River National Wildlife Refuge; California Riparian Habitat Conservation Program; U.S. Army Corps of Engineers Comprehensive Study. **Compatibility with Non-Ecosystem Objectives:** This project will facilitate any levee setback planning processes, which in turn provide floodplain habitats, and also provide improved levee system integrity and non-structural flood control benefits.

Technical Feasibility And Timing

The existing computer model is based on the mechanics of flow and sediment transport in curved river channels (i.e. Johanneson and Parker, 1989; Larsen, 1995; Larsen and Dietrich, 1996), and can be used to simulate migration of an alluvial river. This model relies on mathematical modeling of the physical processes that determine channel shifting in an active alluvial river. The two key processes are bank erosion (Hasegawa, 1989) and the downstream and cross stream velocity distributions. This velocity pattern is the result of the complex interaction between the channel morphology – both the cross section and planform configuration – and the magnitude of the discharge. For example, the location of maximum near-bank velocity changes in a complex way as discharge changes (Larsen, 1995; Larsen, Mount, and Schladow, 1997). Most of these relationships are not predictable empirically. Furthermore, future conditions that have not been experienced in the past are almost impossible to predict empirically (Larsen and Dietrich, 1996).

A version of this model has been successfully used on studies of the Mississippi River (Larsen, 1995), and is the process of being adapted for use on the Sacramento River (DWR, 1998). The output provides practical predictions of the channel planform location in future time periods. Calibration of site-specific bank erosion characteristics can be done through the use of historical planform locations, and direct bank erosion studies (i.e. Larsen and Micheli, 1997). The inputs required for the model are a characteristic discharge (like the 2-year recurrence interval flow), a reach average width, depth, slope, and bed particle size. Previous work with this model has shown it to be effective in modeling the meander migration of the Sacramento River (Larsen et al., 1997a, 1997b, 1999a [in manuscript], 1999b [in manuscript]).

Simulating the effects of levee alignment and channel reconfiguration depend on knowledge of the assumptions embedded in a meander migration model, matching those assumptions with the hydraulic conditions of the simulation in question, and an ability to interpret the results (Larsen, Schladow, and Mount, 1997). For example, it is important to note the degree to which such simulations are descriptions of tendencies, not exact blueprints, and to consider the time scale over which those simulations have significance. We have recently done such a simulation for the Sacramento River near Woodson Bridge State Recreation Area (DWR, 1998; Larsen, Greco, and Barker, in manuscript).

Koll Buer of DWR has developed an empirical method to predict meander migration. Dr. Larsen is collaborating with him to evaluate the strengths and weaknesses of the empirical approach versus the physically-based computer model. Among other things, the empirical model is site-specific, whereas the physically-based predictive model can be rather quickly applied to any channel within the CALFED region.

Implementability: The investigators for this project are available to commence work immediately upon receipt of funding. The development of the model will be closely coordinated with the two on-going floodplain management programs currently being conducted by the ACOE and EPA. Professor Mount has contributed to the ACOE study as part of the Joint Technical Support Group, and as a member of the University of California Water Resources Center advisory panel offering technical support to the California Interagency Floodplain Management Coordination Group.

Monitoring and Data evaluation

Because the levee setback scenarios are not site-specific, this project does not entail monitoring. However, when applied, the GIS-based model that can be produced from this project will form a useful tool for evaluating and monitoring large-scale restoration projects associated with levee setbacks or channel modifications.

Some fundamental questions to be evaluated through this project are: What is the dynamic interaction between levees, hydrology and meander migration? What will be the geomorphic response to levee setbacks? Can setback distances be optimized to promote multi-purpose ecosystem and flood management objectives? How will different setback schemes effect sediment transport?

For **input data** to the model, we will use realistic prototype hydraulic data from the Sacramento and San Joaquin systems. This requires a flood frequency analysis to establish a characteristic discharge (e.g. like the dominant discharge, or the 2-year recurrence interval flow). Typical channel cross sections are used to determine the reach average width and depth at the characteristic discharge. Reach average longitudinal bed slopes can be taken from surveys or topographic maps. The reach average bed particle size may be estimated from bed particle analyses (note that the model is not extremely sensitive to bed particle size.) These data will be taken from **existing data sources** within DWR and the USACOE. A suite of initial channel planforms will be synthesized utilizing sine-generated curves of a range of sinuosities.

Analysis of modeling results. Channel migration causes the erosion of land on one side of the channel, and the development of land (floodplains) on the other side. Spatial analysis of extent of land eroded and extent deposited can be carried out using GIS-based analysis tools. Various levee setback scenarios can be analyzed and quantitatively compared in terms of the magnitude of lands eroded and deposited. Because this occurs over time, a time rate of areal erosion and deposition can be tabulated.

One **question to be tested** is whether there is an optimal distance for levee setback, beyond which there is little ecosystem benefit. This **can be evaluated** by plotting at least two kinds of relationships: 1) the magnitude of spatial change (of both eroded area and newly developed floodplain) versus distance of levee set back, and 2) the time-rate of spatial change (of both eroded area and newly developed floodplain) versus distance of levee set back.

Another important question is varying response between different initial channel planforms and different levee configurations. The same numerical analysis methods can be used (i.e. plotting magnitudes and time-rate of change versus different levee configurations.)

Another analysis is to determine the impact of levee setback scenarios on the sediment transport characteristics of the river. Different setback scenarios will influence the sinuosity of a reach. Because the channel longitudinal bed slope depends on the sinuosity, and sediment transport depends on channel slope, sediment transport characteristics will ultimately be effected by levee setback schemes. (See Larsen, Mount and Schladow, 1997 for an example of this type of analysis.)

The input data, results, and analyses of results will be evaluated by the advisory **peer review** team (DWR, USACOE, TNC, USFWS.) The results will be presented in a report to CALFED, and published in peer-reviewed journal articles.

Question to be Evaluated	Monitoring Parameter and Data Collection	Data Evaluation Approach	Comments
What is the dynamic interaction between levees, hydrology and meander migration?	na	Measure the magnitude of lands eroded and deposited. Tabulate a time rate of areal erosion and deposition. Vary the hydraulic input parameters, like discharge, to examine the effect of changing hydrology.	na
What will be the geomorphic response to levee setbacks?	na	Measure the magnitude of lands eroded and deposited. Tabulate a time rate of areal erosion and deposition. Plot this against the distance of levee setback.	na
Can setback distances be optimized to promote multi-purpose ecosystem and flood management objectives?	na	Plot the magnitude and time rate of lands eroded and deposited against the distance of levee setback. Determine optimum distance for various defined objectives.	na
How will different setback schemes affect sediment transport?	na	Tabulate the change in longitudinal bed slope for various setback schemes. Use the slope to estimate changes in sediment transport rates associated with different schemes.	na

Local Involvement

Since the construction of this model does not involve design or implementation of any restoration projects, we have not sought local support. We will, however, hold two meetings to test the demonstration capacity of the model. At the conclusion of this project, the model simulations will be made available for presentation by public and private groups.

This project will rely upon close coordination between UC Davis, The Nature Conservancy, ACOE Comprehensive Study Group, DWR and USFWS. Members of each agency will participate in an advisory team to direct the development of the model and guide simulations, providing for consistency and coordination with other floodplain management programs. Additionally, the project will interact directly with the on-going California Interagency Floodplain Management Coordination Group and the ACOE Sacramento and San Joaquin Comprehensive Study. The Comprehensive study specifically recommends meander migration simulations. We will coordinate with the U.S. Army Corps of Engineers to make the current work compatible with migration modeling as suggested and outlined in the comprehensive plan. In addition, the meander migration model can be coordinated with the Comprehensive Study's Floodplain Ecosystem Function Model.

Costs And Schedule To Implement Proposed Project

Task 1: Develop new components of meander migration model (Year 1)
Task 2: Apply meander migration model to simulate levee setback scenarios, (First half, Year 2)
Task 3: Develop computer model for visualization of model output (Second half, Year 2)
Task 4: Prepare model simulations, provide report and recommendations (Second half, Year 2)

Budgeted Costs

Task	Direct labor hours	Direct salary and benefits	Service contracts	Material and acquisition costs	Misc. and other direct costs	Overhead and indirect costs	Total cost
Task 1	Research Scientist II 522 hrs; Graduate research assistant 1044 hrs; Undergrad 522 hrs	33500	na	Computer 4500 Grad student fee remission 4932	Printing & copies 2800 Supplies, travel 3000	(10% on all direct costs) 3930	$52662
Task 2	Research Scientist II 261 hrs; Graduate research assistant 522 hrs; Undergrad 261	13587	na	Grad fee remission 2712	Printing & copies 1400 Supplies, travel 1500	(10% on all direct costs) 1649	$20848
Task 3	Research Scientist II 132 hrs; Graduate research assistant 261 hrs; Undergrad 132	6794	na	Laptop 3500 Grad fee remission 1356	Printing & copies 700 Supplies, travel 750	(10% on all direct costs) 824	$13924
Task 4	Prof. II 130 hrs Research Scientist II 130 hrs; Graduate research assistant 261 hrs; Undergrad 130	12794	na	Grad fee remission 1356	Printing & copies 700 Supplies, travel 750	(10% on all direct costs) 1356	$17024
TOTAL		66675	0	18356	11600	7827	104458

Task	Budget Oct-Dec 99	Budget Jan-Mar 00	Budget Apr-Jun 00	Budget Jul-Sept 00	Budget Oct-Dec 99	Budget Jan-Mar 00	Budget Apr-Jun 00	Budget Jul-Sept 00	Total Budget
Task 1	13165.5	13165.5	13165.5	13165.5	0	0	0	0	52662
Task 2	0	0	0	0	10424	10424	0	0	20848
Task 3	0	0	0	0	0	0	6962	6962	13924
Task 4	0	0	0	0	0	0	8512	8512	17024
Total	13165.5	13165.5	13165.5	13165.5	10424	10424	15474	15474	104458

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Schedule Milestones
Task 1: The upgrade of meander migration model will be initiated in the First Year and be completed by the end of the First Year.
Task 2: The application of the model to simulate levee setback scenarios will commence at the beginning of the second year and will be completed by the end of 6 months.
Tasks 3 and 4: The development of the interactive computer visualization of model output, preparation of model simulations, report and recommendations will be prepared for CALFED during the second half of the second year.

The model will be housed at the research facilities at UC Davis, and results of the project will be summarized in a report to CALFED, and published in peer-reviewed journals.

Cost Sharing

DWR supported initial phases of the model development, resulting in findings reported in Larsen and Micheli, 1997; Larsen, Mount, and Schaldow, 1997, and Larsen, Schladow, and Mount, 1997.

Dr. Larsen is currently supported by funds from the USFWS to apply the existing meander migration model to selected reaches of the Upper Sacramento River. The findings of this research are reported in Larsen, Mount, and Schaldow, in review(a), and Larsen, Greco, and Barker, in review(b).

Additionally, Dr. Larsen is proposing to extend the application of the existing model to aid the Riparian Corridor Management Implementation at Woodson Bridge State Recreation Area (a 1999 CALFED proposal by DWR).

The work performed for all of these previous, on-going, and proposed projects will directly support and leverage the support for the currently proposed levee-setback model development.

Drs. Larsen and Mount will also collaborate with ongoing work under the direction of Steven Greco, who is developing a riparian and floodplain vegetation model that depends on the prediction of channel migration.

The UC Davis Center for Integrated Watershed Science and Management and the Geology Department will supply office space, system support, site licenses, and administrative support. In addition, the University will support the salary of Jeffery Mount during the academic year.

Applicant Qualifications

The plan of work will be conducted in laboratories at the University of California, Davis. Dr. Eric Larsen will direct the research and further development of the meander migration model. Drs. Larsen and Mount will direct the preparation of demonstration simulations and the preparation of the final report. Personnel from The Nature Conservancy will assist in meetings that evaluate the model demonstrations.

<u>Eric W. Larsen</u> received his Ph.D. in 1995 from the Environmental Water Resources Division of the Civil Engineering program at UC Berkeley. Prior to receiving his degree he worked extensively as a consultant in the field of geomorphology and river restoration. From 1997 to the present he has been an Assistant Research Geomorphologist in the Department of Geology, UC Davis. His current research interests include application of continuum mechanics to channel migration in meandering

rivers. Based on this research, he has constructed the meander migration model that will form the basis of this study. In addition his research applies the mechanics of sediment transport and flow hydraulics to the development of quantitative techniques for evaluating the impacts of geomorphic change on riverine habitat suitability. On-going projects in the Sierra Nevada and Coast Ranges are focused on establishing and modeling the links between runoff/sediment supply in watersheds and the evolution of stream channels. This work applies quantitative geomorphic models to evaluating habitat conditions for a range of threatened and endangered riparian species.

Dr. Larsen is currently involved in multiple collaborative research projects that directly involve graduate students. These include joint projects on: channel dynamics of the Sacramento River (USFWS); quantitative evaluation of channel adjustments to changing sediment supply (UC Center for Water and Wildlands Research); links between stream dynamics and groundwater tables (U.S. Bureau of Reclamation); and geomorphic controls on habitat conditions in mountain streams (California Department of Parks and Recreation).

Jeffrey F. Mount received his B.A. in Geology from UC Santa Barbara (1976), and his M.A. (1978) and Ph.D. (1980) in Earth Science from UC Santa Cruz. From 1980 to the present he has been a professor in the Department of Geology at UC Davis. During this time he has conducted research on sedimentation and stratigraphy, with an emphasis on process sedimentology of marine and non-marine depositional systems. His current research interests include: analysis of the hydrogeomorphic evolution of rivers in response to changing land use conditions; geochemical and petrologic identification of anthropogenic sediment sources within the Sacramento River watershed; and mechanics of geomorphic recovery in riverine systems affected by catastrophic sedimentation events. He is the author of *California Rivers and Streams: The Conflict between Fluvial Process and Land Use*, 1995 (UC Press).

During his 17 years at UC Davis he has supervised more than 20 graduate students and successfully managed nine large National Science Foundation grants and several American Chemical Society grants. He is currently the Principal Investigator or Co-Principle Investigator on four federally-funded, multidisciplinary grants that focus on watershed issues in the state of California. He serves as a member of several multiagency task forces focusing on floodplain management within the state, is the current Chair of the Department of Geology at UC Davis, and the Director of the UC Davis Center for Integrated Watershed Science and Management.

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